ESTIMATION ON GAS DENSITY INTERNAL MODEL CONTROL (IMC) CONTROLLER USING PARTIAL LEAST SQUARES

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A thesis submitted to the Faculty of Chemical and Natural Resources Engineering in partial fulfillment of the requirements for the Degree of Bachelor of Engineering

in

Chemical Engineering

Faculty of Chemical and Natural Resources Engineering
University Malaysia Pahang

April 2009

ACKNOWLEDGEMENT

Praise be to God for His help and guidance that finally I am able to complete this final year project as one of my requirement to complete my study.

First and foremost I would like to extend my deepest gratitude to all the parties involved in this research. First of all, a special thanks to my supervisors Mr. Noor Asma Fazli bin Abdul Samad and Miss Fathie Bte Ahmad Zakil in his and her willingness in overseeing the progress of my research work from its initial phases till the completion of it. I do believe that all their advice and comments are for the benefit of producing the best research work.

Secondly, I would like to extend my words of appreciation to all my lecturers in the Faculty of Chemical Engineering and Natural Resources (FKKSA), for their support and motivation during this project development.

To all my close friends and all my course mates, thank you for believing in me and helping me to go through the difficult time. The experiences and knowledge I gained throughout the process of completing this final project would prove invaluable to better equip me for the challenges which lie ahead. Last but definitely not least to my family members, I can never thank you enough for your love, and for supporting me throughout my studies in University Malaysia Pahang (UMP).

ABSTRACT

This research was carried out to develop a gas density control model using Aspen Plus with Internal Model Control (IMC) method application for data generation purpose and to analyze on the process estimation using Partial Least Squares (PLS) regression. In making this process, the Air Flow Pressure Temperature (AFPT) pilot plant is use as the case study. The AFPT pilot plant is a process control training system (PCTS) that uses only air to simulate gas, vapor or steam. This AFPT pilot plant is a scale-down Real Industrial Process Plant built on 5ft X 10ft steel platform, complete with its own dedicated control panel. The AFPT pilot plant can be use to control the gas density by manipulating the pressure, flow, and temperature of the plant. This AFPT pilot plant then will be simulating using Aspen Plus to develop a gas density control model. The model will be run in steady-state and dynamic mode. In dynamic mode, the controller for all the parameters to control the gas density is putted. This entire controller then will be tune using the Internal Model Control (IMC) method in order to get its best performance. After the simulation is done, the gas density data generated from the simulation will be compared with the actual (experiment) data for validation of the data. The data shows that the error between the two data is less than 5%, meaning that the data generated from the simulation is valid. Then, this data will be use to develop a process estimator model using Partial Least Squares (PLS) method. After the estimation model is done, the mean squares error (MSE) between the estimated data and actual data is 0.001584743. This shows that the Partial Least Squares can be use as the estimator model for gas density control purpose and the estimation model developed is reliable.

ABSTRAK

Kajian ini dijalankan adalah untuk membangunkan alat kawalan ketumpatan udara menggunakan Aspen Plus dengan applikasi Internal Model Control (IMC) bagi tujuan pengumpulan data dan untuk menganalisis proses penganggaran menggunakan cara Partial Least Squares (PLS). Dalam kajian ini mesin Air Flow Pressure Temperature (AFPT) digunakan sebagai kajian kes. Mesin AFPT adalah alat latihan proses kawalan bagi simulasi udara, steam atau wap air. Mesin AFPT ini adalah diambil daripada applikasi berdasarkan industri yang sebenar dilengkapi dengan kesemua alat kawalan yang terkini. Mesin AFPT ini kemudian akan disimulasikan menggunakan applikasi Aspen Plus bagi tujuan untuk membangunkan alat kawalan ketumpatan udara. Simulasi ini dilakukan dalam dua keadaan, iaitu dalam keadaan statik dan dinamik. Dalam simulasi dinamik, alat kawalan diletakkan di setiap alat di dalam simulasi AFPT bagi tujuan memanipulasikan proses. Setiap alat kawalan ini akan dikemaskini menggunakan Internal Model Control (IMC). Ini bertujuan bagi mendapatkan prestasi kawalan yang lebih baik daripada alat kawalan terbabit. Selepas simulasi ini dijalankan, data yang terhasil akan dibandingkan dengan data daripada eksperimen. Hasil daripada perbandingan kedua-dua data ini, mendapati, perbezaan data simulasi dengan eksperimen adalah kesemuanya kurang daripada 5%. Dengan itu, ini telah menjelaskan akan kesahihan data simulasi tersebut. Data-data daripada simulasi ini seterusnya digunakan dalam membina atau membangunkan model penganggaran menggunakan cara Partial Least Squares (PLS). Selepas pembangunan model penganggaran ini dilakukan, perbezaan data daripada proses penganggaran dan data simulasi adalah 0.001584743. Perbezaan yang sangat kecil ini menunjukkan bahawa data daripada model penganggaran menggunakan cara PLS ini boleh dipercayai dan pembangunan model penganggaran telah berjaya dibangunkan bagi tujuan pengawalan ketumpatan udara.

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IMC	Internal Model Control
PLS	Partial Least Squares
AFPT	Air Flow Pressure Temperature
EOS	Equation of State
PID	proportional-integral-derivative
PI	proportional-integral
P-controller	Proportional Controller
PV	process variable
RHP	Right half-plane
AR	amplitude ratio
ISE	Integral Square Error
PCA	Principal Component Analysis
NIPALS	Non-linear Iterative Partial Least Squares
MLR	Multiple Linear Regression
SSE	sum square error
RMSE	root mean square error
MAPE	mean absolute percentage error
MSE	mean square error

EPV	explained prediction variance
PCTS	process control training system
FCV	Flow control valve
FT	flow transmitter
TIC	temperature controller
PT	pressure transmitter
DT	density indicator
K_p	steady state gain
t_D	dead time
τ_C	time constant
lv	latent variable

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CHAPTER I

INTRODUCTION

1.1 Introduction

Stringent product specification, stiff competition among manufacturers and increasingly strict regulation from local authority in the face of full capacity operation with zero accidents and emission have forced many existing plants to revamp their existing control system. More advanced control schemes have been implemented. Despite these successful implementations, many issues remained as hindrances to efficient process control. For example, the success in the implementation of any optimization scheme requires adequate performance of all control loops. This is however, sometimes hampered by two issues. The first is related to inadequacy of conventional controller used since chemical process dynamics are typically non-linear whilst the controllers are based on linear theory. The second issue is associated with process measurement, the accuracy of which is a prerequisite to successful process control.

Since measurement devices are not one of the main factors in achieving effective process control, selection of appropriate sensors and their location should be properly consider. However, not all variables in a process plant are readily to be measured on-line. Product quality variables such as chemical concentration and their composition are rarely available on-line, and are usually obtained by laboratory sample analysis. This is usually performed at long intervals and is therefore not practical to be used for process control. Over the years, various on-line measurement devices have been developed. However, many of these on-line devices are still suffering from problems due to the availability, reliability, complexity and large delays. For some quality variables, existing analytical tools used are simply unavailable for on-line applications. Hence, the development of inferential estimation and control has been advocated as one of the alternative solution to deal with measurement difficulties.

1.1.1 Background Of The Study

Gas density represents one of the gas properties which need to be set precisely in a few processes such as combustion (i.e. furnace and motor engine), polymerizations process as well as chemical industries. Research on the effect of gas density in chemical processes has been conducted in the recent decades, for examples, gas density effect on mass transfer in bubble and slurry bubble column and the effect of gas density in frequency response of gas-filled pressure transducers. Therefore gas density requires to be controlled.

In feed back control, controlled variable compared to set point and then calculated in the controller. Output of controller then adjusts the manipulated variable in order the controlled variable is equal to setting point. Control strategy can be conducted either indirect or direct. Direct control is chosen if measurement controlled variable is available, and vice versa. For example, control gas density can be conducted by controlling pressure or temperature, because based on PVT gas correlation, gas density is a function of pressure,P and tempertature,T. However, indirect strategy usually gives unfavorable performance.

Another strategy which is commonly used by inferential model instead of unavailable sensor of controlled variable. This model is developed from available measurements i.e. temperature, rate flow and pressure. The model can be developed first principal, semi-empirical or empirical model.

In this study gas density model will be developed base on Internal Model Control (IMC) method. IMC is one of the techniques that are used to determine a controller setting. The objective of IMC method is to provide a good initial controller setting that can subsequently be fine tuned on-line. The model is then implemented to PID controller of gas density with equipment based on AFTP control system (Air Flow Temperature and Pressure control system).

1.2 Identification Of Problem

In recent years, changing industrial needs and advances in computer technology had gives some impact in education, research, and practice of process control. From industrial perspective, improved in productivity, efficiency, and product quality goals generated a demand for more effective operational strategies to be applied in the production line, while the developments in digital computers and communications have revolutionized the practice of process control and allowed more advanced tools to be implemented. As a consequences, a vast broadening of the domain of what is technologically and economically achievable in the application of computers to control industrial process. This domain now includes process information and data gathering, control, and online optimization, and even production scheduling and maintenance planning function.

In chemical industries, process control gives many contributions in assuring a smooth process. In industries, many of the process involve liquid, solid and gas. All the parameter involved should always be in the rightful manner. A slight miscalculation might bring to accident, loss in productivity, increase the operating cost or loss of operational time. This is where process control gives a contribution role in preventing that all the risk mention before might not happen.

There are many factors that can give an effect in a chemical process. One of the factors is the gas density. Gas density has its own effect in some chemical process, for example the gas density effect on mass transfer in bubble and slurry bubble column. Base on its importance in chemical process, research on gas density measurement is performed to measure and control the gas density in some chemical process. To control the gas density in a chemical process means to control the effect of it in the process itself. Gas density is strongly influenced by temperature and pressure; therefore there are ideas that maybe by controlling this two variables, the gas density in a process can be controlled too.

In order to control a variable in a pilot plant, a controller is needed. By introducing a controller such as cascade control or PID in a pilot plant, the gas density that is required in some process can be measured and control accurately. But, the controller design that was proposed to be use in any chemical process needs to be proven its effectiveness first. With the advance of computer technology in industry, a simulation model can help in testing the effectiveness of the proposed controller design. Therefore, in this research, a pilot plant equipment will be simulated using software to test the effectiveness of a controller design then, the gas density resulted from this controller will be estimated using Partial Least Squares (PLS) Method.

1.3 Objectives:

In this research, there are two (2) main objectives. The two objectives of this research are:

i. To develop a gas density control model using ASPEN PLUS with Internal Model Control (IMC) method application for data generation purpose
ii. To analyze on the process estimation using Partial Least Squares (PLS) method.

1.4 Scope Of The Study:

To achieve the objectives of the research, this scope of study are to be apply:

i. Develop an AFPT simulation model using ASPEN PLUS with the introduction of a controller set using Internal Model Control (IMC).
ii. Generate data from the ASPEN PLUS simulation.

iii. Validating the data from ASPEN PLUS model by comparing it with the data from the actual model (experiment)
iv. Analyze dynamic response of AFPT simulation model.
v. Analyze the process estimation using Partial Least Squares (PLS) method.

1.5 Significances Of Study

For decades, research on effect of gas density towards chemical process has been performed. Gas density has its own effect on some chemical process, such as gas density effect on mass transfer in bubble and slurry bubble column and effect of gas density in frequency response of gas-filled pressure transducers. Because of the importance of the gas density towards some chemical process, research has been done in order to control the gas density. But, gas density is hard to be controlled, therefore, it is important to develop a model that is equipped with the density control strategy. With a good control system strategy, robustness or fault in a process can be eliminated, and a more effective process can be achieved. Also, a good control system can assured in maintaining some level of desired performance. Moreover, a control strategy aims to keep the operating condition variations at a minimum, and allow the operating target to stay as close as possible to the true (optimal) maximum profit. The control system is expected to minimize the variations around the operating target (performance objective) while, in turn, shrinking the tolerable operating limits. The more advanced the control system is, the better the chances are that the plant will operate even closer to the optimum target. This gain, quantified by the move toward a more profitable regime, helps establishing the financial benefits of the control system.

CHAPTER II

LITERATURE REVIEW

2.1 Gas Density

Gas density represents one of the gas properties which need to be set precisely in a few processes such as combustion, polymerizations, as well as chemical industries. Also, density is heavily affected by temperature and pressure in many cases. By knowing the temperature, pressure, and composition, an accurate density can be calculated by using the proper Equation of State (EOS).

However, the accuracy of such an equation of state (EOS) in turn depends on the accuracy of the experimental data use to establish it. Therefore, because of this factor, to develop a references quality EOS, reliable thermodynamic property measurements of the fluids must be available. Gas density has its own effect in chemical processes. For example, the effect of gas density on mass transfer in bubble and slurry bubble column, and gas density effect on frequency response of gas-filled pressure transducers For this reason, many research has been done in order to control the gas density whether by developing a measurement device to measure the density accurately or by developing a controller to control the gas density in a desired value.

2.2 Control Law

A control signal c(t) is calculated, given the value of the error e(t) through a predefined equation:

$$c(t) = C\,[e(t)] \qquad \textbf{(2.1)}$$

The function C[.] constitutes the control law. By specifying C[.] , we are, in effect, establishing the manner which the error information is utilized by the controller. The most common functional form is the three mode proportional-integral-derivative (PID) control law.

2.2.1 Proportional Mode

This mode produces a control signal that is proportional to the error.

$$c(t) = k_c e(t) + c_b \qquad \textbf{(2.2)}$$

k_c represents the proportional gain of the controller, and defines how sensitive the controller is to errors present in the system. c_b is bias signal that corresponds to the value of control signal when error is zero. The bias signal can also be interpreted as the steady-state value of the control signal. Thus, defining the deviation variable c(t) = c(t) - c_b, and recognizing that by definition e(t) = e(t), Eq (2.2) results in the following transfer function:

$$\frac{\bar{c}(s)}{\bar{e}(s)} = g_c(s) = k_c \qquad \textbf{(2.3)}$$